Recitation Problems for Week 9, Tuesday

6.C13. Consider an atomic nucleus with Z protons which has no electrons orbiting it. The energy levels for a single electron in such a system is given as

$$E_n = -\frac{Z^2(13.6\,eV)}{n^2}.$$

If the depth of the lowest energy level is more than two $m_e c^2$, then it is energetically favorable to create an electron-positron pair from the vacuum and bind the electron to the nucleus. What is the minimum value of Z for this to occur?

6.C29. At what temperature is the population of the third excited state of Hydrogen equal to 5% of the ground state?

6.S55. (a) The Hydrogen-iodide molecule, HI, can be approximated using a Morse potential. Measurements of the spectrum give the frequency associated with the vibrational energy as $f = 6.93 \times 10^{13}\,Hz$. Assuming that only the Hydrogen atom is moving, what is the spring constant, k, for HI? (b) Measurements also yield that the depth of the well is $4.887 \times 10^{-19}\,J$, what is α in Equation 6.11? (c) The equilibrium separation is found to be $r_0 = 1.604 \times 10^{-10}\,m$, over what range of r is the potential accurately modeled (within 25%) by a harmonic oscillator?

6.S62. A Λ particle has a mass of $m_\Lambda = 1107\,MeV/c^2$. It can decay into a proton and a pion. (a) Show that the relativistic energy of the out-going pion can be expressed as

$$E_\pi = \frac{(m_\lambda c^2)^2 - (m_p c^2)^2 + (m_\pi c^2)^2}{2m_\lambda c^2}.$$

(b) Similarly, the energy of the outgoing proton can be shown to be

$$E_p = \frac{(m_\lambda c^2)^2 - (m_\pi c^2)^2 + (m_p c^2)^2}{2m_\lambda c^2}.$$

In looking at the proton from the decay of a Λ at rest, do we need to worry about relativistic effects? (Hint: compare the energy of the proton to its rest mass.)